Modeling the Impact of Seascape Evolution on the Seismic Response of Shelf and Slope Strata

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LONG-TERM GOALS

My long-term goals are to improve our understanding of the seabed on the continental shelf and slope and its evolution over geologic time, as well as to enhance our ability to extract geologic information about the seabed from geophysical data.

OBJECTIVES

The specific objectives of this project are to:

(1) Model the potential changes to the seismic response of the seabed offshore of river mouths caused by flood sedimentation and storm reworking (addresses EuroSTRATAFORM Task D2).

(2) Constrain the time and space scales over which different shelf and slope processes produce a stratigraphic record that is detectable in seismic reflection data (addresses EuroSTRATAFORM Task D5).

(3) Model what is and is not preserved of the stratigraphic record across continental shelves and slopes over geologic time (addresses overarching goal of EuroSTRATAFORM).

Progress has been made on all three objectives, but because of space limitations, this summary focuses on the accomplishments made during FY04 toward the first objective, for these have been the most significant.

APPROACH

While seldom resolved in seismic reflection data, flood deposits have the potential to modify the seismic response of the seabed offshore of rivers by altering the physical properties of the surface such as grain size distribution, bulk density and porosity. We (I along with my EuroSTRATAFORM collaborators James Syvitski and Eric Hutton [INSTAAR]) are assessing the acoustic significance of such changes (objective #1) by simulating the evolution of flood-derived and storm-modified shelf strata using SEDFLUX2D (Syvitski and Hutton, 2001) and then using its predictions for seabed grain size, porosity and bulk density as inputs to the Buckingham model (1997, 1998, 2000) to also estimate compressional speed. While other, more sophisticated acoustic models exist, the relative simplicity of the Buckingham model fits well with the level of sophistication of many of the process algorithms used

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14. ABSTRACT
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15. SUBJECT TERMS

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in *SEDFLUX2D*. Furthermore, the Buckingham model yields sound speeds for different seabed sediment mixtures that are in good agreement with measurements. Since our focus is on the impact of floods and storms on the acoustic response of the seabed, we have used the compressional speeds with the bulk densities to model impedances ($I = \rho_b V$) and ultimately seabed reflectivies ($R = \frac{I_{bed} - I_{water}}{I_{bed} + I_{water}}$).

WORK COMPLETED

Executing the approach outlined above, we have generated four 200y long simulations of changes in seabed reflectivity in the western Adriatic. Two of these have been carried out using a sediment discharge record modeled for the Po River, while the other two were produced using a sediment discharge record modeled for the Pescara River (Fig. 1A). Both discharge records were simulated using the HYDROTREND module of SEDFLUX2D (e.g., Fig. 1B.1.iii). Of the two Po-based stratigraphic simulations, one includes the impact of waves, while the other does not. This also holds for the two Pescara-based simulations (Fig. 1A). The simulations that include the impact of waves used a stochastic model of wave climate derived from a long-term directional recording of waves in the northern Adriatic (Fig. 1B.2.iii)(Cavaleri et al., 1997). The four simulations are not an attempt to reproduce the shelf strata offshore of the Po and Pescara Rivers. Instead, they are designed to assess the relative impacts of floods and storms on the seabed using realistic inputs and boundary conditions for the modeling.

RESULTS

Both the Po- and Pescara-based model runs produce deltas when only plume-sedimentation is simulated. The modeled Po discharge is an order of magnitude greater than the modeled Pescara discharge, so the delta that forms in the former run is larger and progrades more than three times farther than the one that forms in the latter run. A more dramatic difference between the model runs results when the impacts of waves of varying heights and periods are also included in the simulations. The wave activity inhibits shallow-water deposition by reworking and moving a fraction of the plume deposits further offshore and out of the model. The decrease in accumulation is the same for both river inputs, but in the Po-based simulation, sediment supply is great enough that a delta still forms, while in the Pescara-based simulation (Fig. 1A.2), wave reworking exceeds the sediment supply and no delta forms.

Reworking of plume deposits by waves has an equally significant effect on the acoustic character of the seabed. When only plume sedimentation is simulated, seabed reflectivities are produced that decrease an estimated 1dB with increasing water depth (e.g., Fig. 1B.1.i&ii). Almost all of this change occurs over the upper foreset of the deltas. The greatest temporal changes in seabed reflectivity occur in this region as well and are also on the order of 1dB. This is because the varying discharges to the deltas lead to plumes of different extent that in turn deposit variable grain sizes over a distance from the river mouth that expands with plume length.

This pattern is significantly modified by the inclusion of wave activity (e.g., Fig. 1B.2). For both river inputs, waves act to essentially halve the variation in seabed reflectivity with water depth by raising the overall reflectivity of the seabed in deeper water (Fig. 1B.2.i&ii). The waves accomplish this in the model by winnowing out sediments that can be moved into deeper water, leaving behind a coarser, higher-velocity and thus more reflective lag. As a consequence, reflectivities found only within 5-

10km of the river mouth in the plume-only simulations extend across the breadth of the models in the plume-plus-waves simulations.

Variable wave activity also appears to increase the temporal variability of seabed reflectivity. In the Po-based simulation, offshore regions that showed constant reflectivity with time in the plume-only run change between ±0.25-0.5dB on a 1-5y timescale in the plume-plus-wave run. Changes of equal magnitude appear to be even more frequent in the Pescara-based simulation (Fig. 1B.2.i&ii). This is due to the lower sediment supply in this simulation, which increases the relative impact of the waves. However, note that the offshore reflectivities in the Pescara simulation are tending towards a new (albeit higher) state of constant reflectivity (Fig. 1B.2.i). The run presages what would happen in the model if no further sediment were supplied. The waves would produce a stable across-shelf distribution in grain size that would be equilibrium with the wave climate and would not change with time.

IMPACT/APPLICATIONS

Our modeling suggests that flood sedimentation and reworking by waves can produce changes in seabed reflectivity in the near shore of 1dB with increasing water depth and 0.25-0.5dB from one year to the next at any given water depth within 30m of the shore. It also suggests while the acoustic characteristics of shelf sediments at anyone location may be too difficult to predict because of unknowns about the geologic history of that location, it may still be possible to estimate how likely those properties are to change over the course of years to decades. The most unchanging continental shelf setting from an acoustic standpoint will be one that is receiving no significant sediment input and is in equilibrium with the existing wave climate. If correct, then acoustic measurements from these settings need to be made only once in order to characterize the spatial variability of the seabed. By contrast, shallow-water regions in the vicinity of rivers are likely to change with time. And if wave-activity in the region is significant, the temporal variability may be even greater. Thus in these settings, repeat acoustic measurements may be necessary to accurately characterize the current acoustic environment.

RELATED PROJECTS

I along with others in a subgroup of the Seabed Team in the Uncertainty DRI (Drs. Kraft (UNH), Overeem (INSTAAR), Holland (PSU), Syvitski (INSTAAR), Mayer (UNH) and Goff (UTIG)) have tested the capability of SEDFLUX2D to predict grain size and compressional sound speed in the GEOCLUTTER study area on the New Jersey continental shelf. In the test, SEDFLUX was used to model seabed evolution on the shelf from ~40Ky ago up to the present. The final model outputs of grain size, porosity and bulk density were then used in the Buckingham (1997, 1998, 2000) and EDFM (Williams, 2001) acoustic models to compute compressional sound speeds. Finally, these predicted sounds speeds and grain sizes were compared against measured in-situ sounds speeds and grain size analyses from cores.

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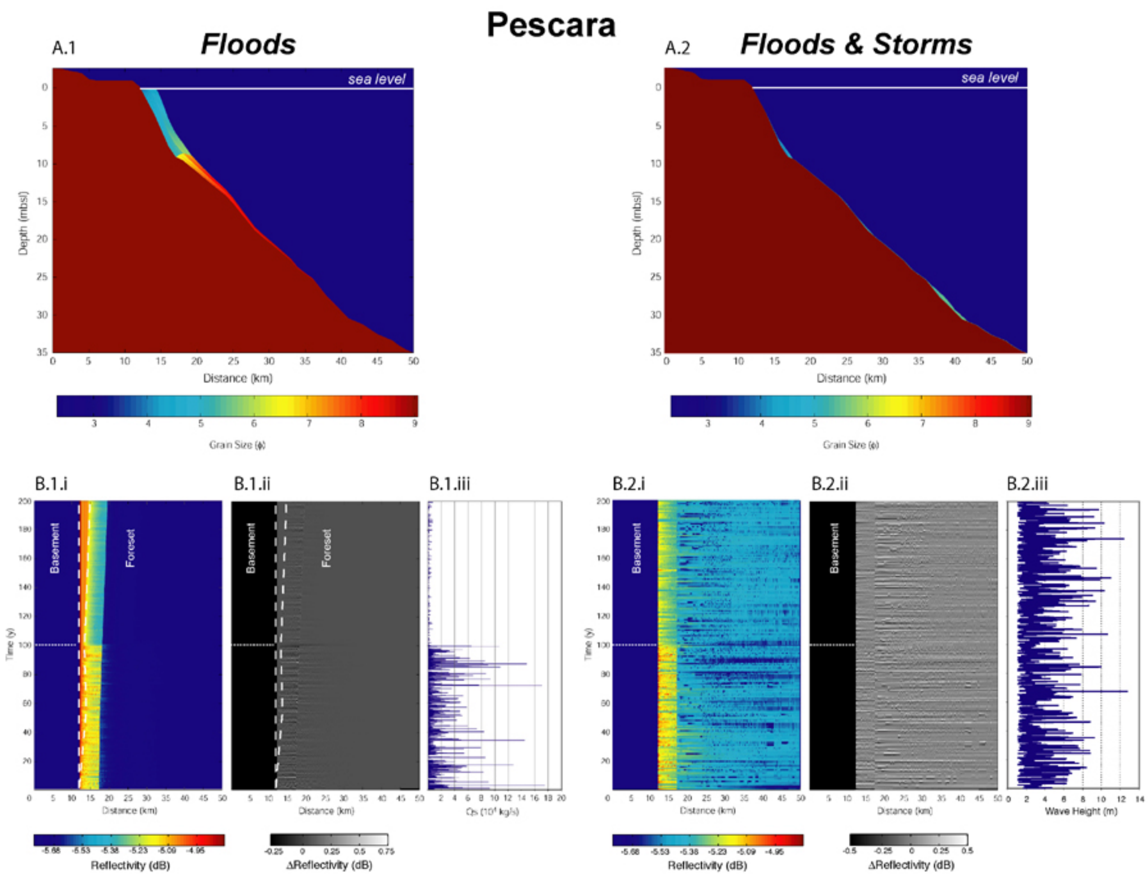

Figure 1. SEDFLUX2D simulations of 200y of seabed evolution in the nearshore by flood sedimentation without (A.1) and with (A.2) storm reworking. Flood sedimentation is based on modeled sediment discharge for the Pescara River (B.1.iii). Storm reworking is based on stochastic model of wave activity (B.2.iii). Seabed reflectivities are predicted to change ~1dB offshore (B.1.i, B.2.i) and 0.25-0.5dB from one year to the next (B.1.ii, B.2.ii).